THE MONTHLY NEWS MAGAZINE OF THE NATIONAL BUREAU OF STANDARDS

DIMENSIONS NBS

75 Years
National Bureau of Standards

Adapted from "Ode on Science"
A song by Jezaniah Sumner, 1798
See page 2.

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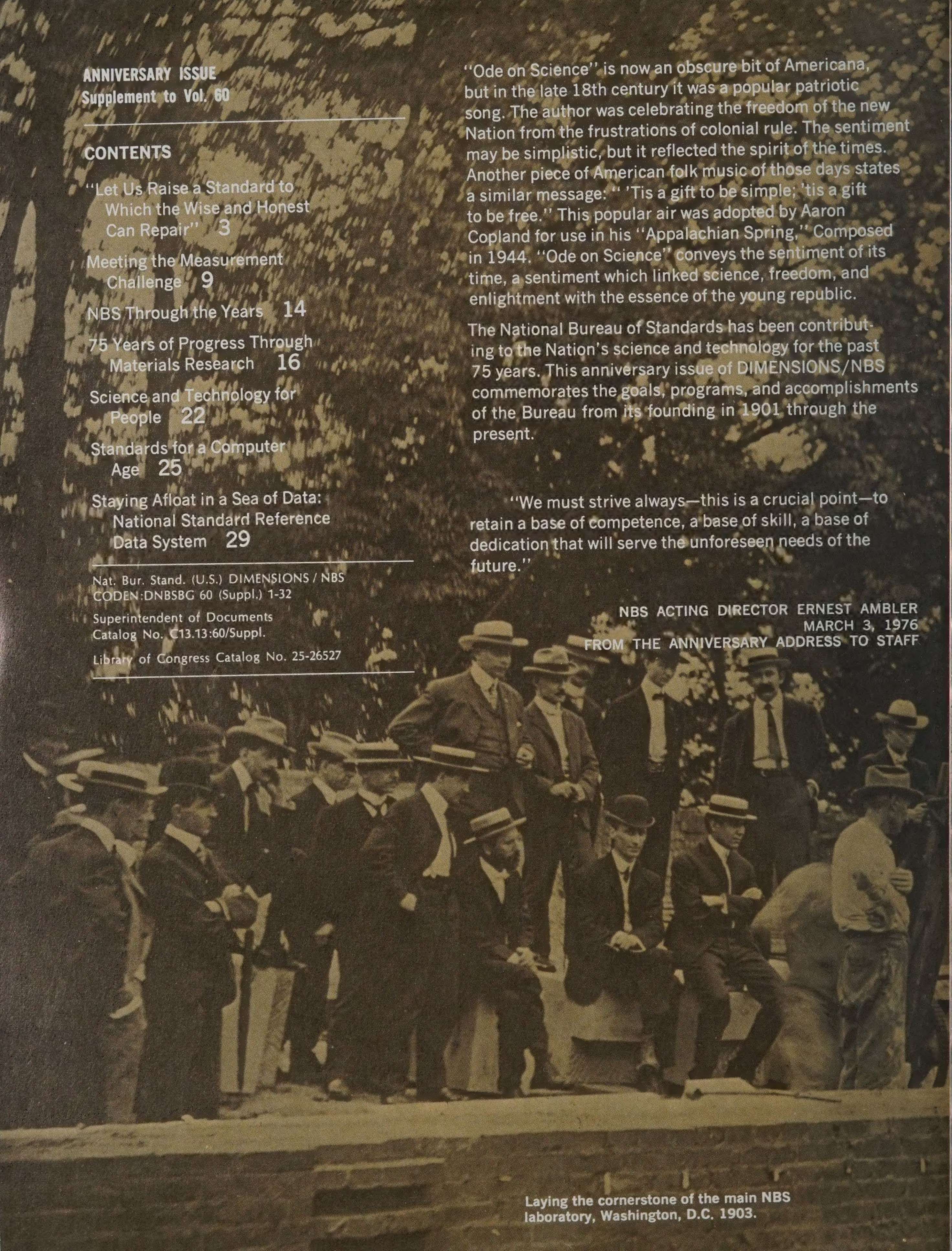
"Ode on Science" is now an obscure bit of Americana, but in the late 18th century it was a popular patriotic song. The author was celebrating the freedom of the new Nation from the frustrations of colonial rule. The sentiment may be simplistic, but it reflected the spirit of the times. Another piece of American folk music of those days states a similar message: " 'Tis a gift to be simple; 'tis a gift to be free." This popular air was adopted by Aaron Copland for use in his "Appalachian Spring," Composed in 1944. "Ode on Science" conveys the sentiment of its time, a sentiment which linked science, freedom, and enlightment with the essence of the young republic.

The National Bureau of Standards has been contributing to the Nation's science and technology for the past 75 years. This anniversary issue of DIMENSIONS/NBS commemorates the goals, programs, and accomplishments of the Bureau from its founding in 1901 through the present.

"We must strive always—this is a crucial point—to retain a base of competence, a base of skill, a base of dedication that will serve the unforeseen needs of the future."

NBS ACTING DIRECTOR ERNEST AMBLER
MARCH 3, 1976
FROM THE ANNIVERSARY ADDRESS TO STAFF



Laying the cornerstone of the main NBS laboratory, Washington, D.C. 1903.

'Let Us Raise A Standard to Which The Wise and Honest Can Repair'*

by Juli Kelley
editor, DIMENSIONS/NBS

America 1900:

700 cars were on the road at the beginning of the year. Before it ended, 4,000 more had rolled off the production line. Half a million households had telephones. Electric lights burned in a few New York City shops and homes. Chicago had skyscrapers, Boston a subway. The phonograph and the gramophone amazed and amused people.

A few Americans made a lot of money that year, but most barely got by. Andrew Carnegie made $23 million. Two-thirds of the Nation's workers earned less than $600.

Monopolies controlled very profitable markets from coal to wire nails. Business was booming. The United States was becoming a world power industrially and commercially.

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* George Washington, Constitutional Convention 1789

Raise A Standard
continued

But . . .

A pound of butter at the shop on the corner might weigh more than a pound of butter at the shop in the middle of the block. Inaccuracies in railroad scales caused disputes about taxes and charges. Scientists looked abroad for precise instruments. Industries, especially the new electrical industry, lacked adequate standards.

These conditions convinced Congress that the United States needed a Federal science laboratory to maintain and develop standards for commerce, science, and industry. So, in 1901 President McKinley signed the act that created the National Bureau of Standards.

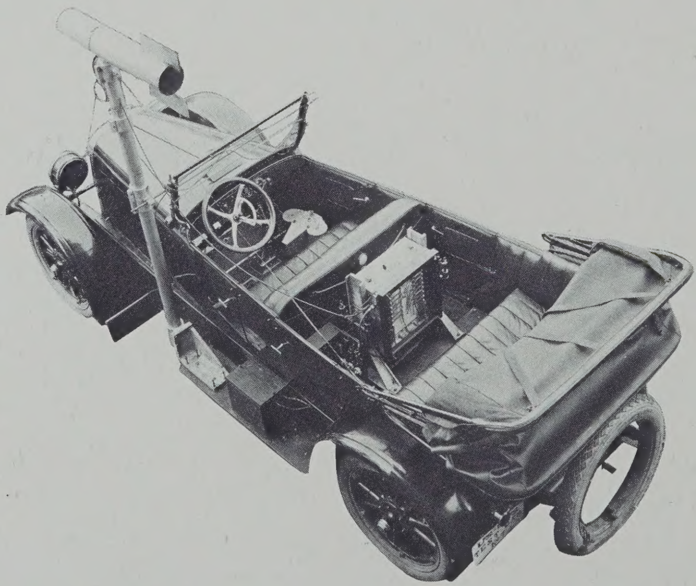
Within a decade, the new Bureau began to bring harmony to measurement practices in commerce through uniform, legal weights and measures. The first NBS director established a National Conference on Weights and Measures in 1907 for officials who would use the Bureau's measurement expertise as a basis for State and local regulations. Today the Conference, still meeting annually, continues to develop model laws for adoption by the States as conditions continue to change. A special challenge now faces the NCWM as the Nation prepares to convert to predominant use of metric units.

By 1913 public indignation over the inaccuracy of railroad scales prompted the Interstate Commerce Commission to turn to NBS for aid. Bureau staff took to the rails in a car specially equipped for checking and adjusting scales. This activity also continues today.

These accomplishments, important as they are to fair trade, reveal only one aspect of the work of the National Bureau of Standards. Going back again to 1901, we find just taking shape a research organization—one that would work in every area of the physical sciences and engineering and would affect every segment of society.

In keeping with the American tradition of rising from humble beginnings, the new Bureau settled into cramped quarters in downtown Washington, D.C. with meager funds and little equipment. But Congress did provide for the building of two major laboratories, and, most propi-

Shown here are the members and assistants of the International Technical Committee of 1910, the first such group to meet at the Bureau. Their objective was to establish internationally-agreed values for the ohm, volt, and ampere. Measurement needs in electricity were foremost among the conditions that led Congress to establish NBS. In the late 19th century, the infant electrical industry could not measure the volt, ampere, ohm, watt, or candle with sufficient accuracy. The confusion that reigned at home and abroad is illustrated by the fact that a lamp drawing 10 amperes at 45 volts was called 2,000 candlepower in the United States, 400 candlepower in Britain, and 500 candlepower in Germany.



In the 1920's the National Bureau of Standards was using its own specially designed apparatus to measure and record 18 points of automobile performance. This touring car had an instrument mounted on the running board to measure wind speed and direction relative to the car. On the floor of the front seat was a device for recording the instantaneous rates of gasoline flow to the carburetor.

tious, it gave the Bureau a director of immense personal strength and resources, Dr. Samuel Wesley Stratton.

Ralph Waldo Emerson said that history is the lengthened shadow of a man. Certainly for the almost 22 years of his tenure, Stratton molded the institution as none other has done. His influence remains indelible. He immediately began to hand pick his staff (numbering 12 in 1901) and to direct it to establish competence in basic science. He chose the future site of the Bureau (the corner of Van Ness Street and Connecticut Avenues in Washington) and got construction of the laboratories underway. Most important, he dealt effectively with the Congress in acquiring the support he needed to chart the future of the Bureau.

What was the institution Stratton envisioned? In 1900 most precision measuring instruments were foreign-made. Even those produced here had to be calibrated abroad. Many measurement procedures were inadequate—as in the important area of electricity measurement. Manufacturers lacked standards for quality control in the production of materials and products. They needed an understanding of the materials they were dealing with. They lacked standards and methods for industrial measurements. Stratton envisioned an institution capable of responding to all these needs. He knew it would take time, money, a competent and dedicated staff, and research to establish that capability. As one of the drafters of the legislation creating NBS, Stratton made sure that he and the organization would have the latitude necessary to succeed. Brief but important clauses of the enabling act said:

> "The functions of the Bureau shall consist in the custody of the standards; (of weights and measures)
>
> The comparison of the standards used in scientific investigations, engineering, manufacturing, commerce, and educational institutions with the standards adopted or recognized by the Government;
>
> The construction when necessary of standards, their multiples and subdivisions;
>
> The testing and calibration of standard measuring apparatus;
>
> The solution of problems which arise in connection with standards;
>
> The determining of physical constants and the properties of materials, when such data are of great importance to scientific or manufacturing interests and are not to be obtained of sufficient accuracy elsewhere."

Stratton was personally responsible for the key clause: ". . . the solution of problems which arise in connection with standards." Interpreted broadly, this clause authorizes many types of research. If the subject concerns the quality of the environment . . . public safety . . . mass production

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Above. Dr. Samuel Stratton, first NBS director, at his desk in the main building at the first permanent Bureau location, Washington, D.C., 1905.

Right. The first Bureau railway car, used to transport equipment for standardizing railroad track and master scales. Public indignation over the inaccuracy of such scales led in 1913 to the establishment of this service. NBS continues this activity today, under direction of the NBS Office of Weights and Measures. OWM also assists State and local government officials in achieving "equity in the marketplace" through accurate weights and measures and fair weighing and measuring practices.

Raise A Standard

continued

. . . the composition of a material—standards are involved, whether they are standards of measurement, practice, quality, or performance.

Stratton saw the enabling act as an entree into "99 percent of the field of research." It remained for him and others to turn words into action for the Bureau's many clients: science, industry, the individual citizen, and all levels of government.

Science

In the first 3 years, the Bureau spent most of its time developing basic competence and acquiring the instruments necessary to perform research, both basic and applied.

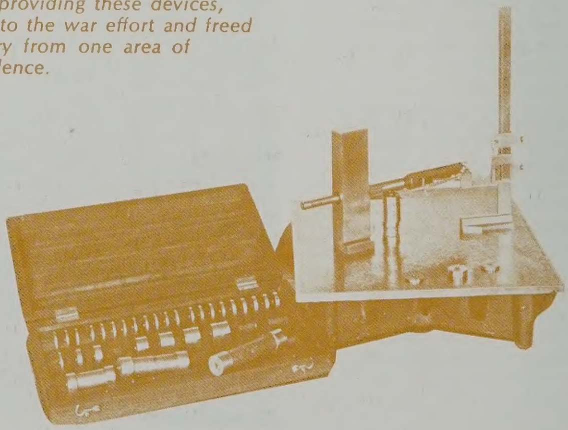
Although the line between the two is often unclear, basic science provides the raw material—the fundamental knowledge—while applied science uses this knowledge to solve the problems and meet the challenges of daily life. When Einstein stated his theory of relativity in 1905, the achievement was part of basic science; when today we light a home with energy from a nuclear power plant, that application is a result of applied science.

Over the years NBS research has laid the groundwork for undreamed of advances in electricity, aviation, automotive engineering, and materials such as plastics and building materials. It has provided essential improvements in electrical standards and developed better standards of length and new standards of light, temperature, and time. The Bureau has pioneered work in the areas of aeronautics, radio, cryogenics (extreme low temperature studies)—to name a few.

Throughout the history of NBS, the relative emphasis on basic research as compared to applied research has fluctuated continually. For example, applied work during both World Wars and Korea demanded the full effort of staff resources. Funding for basic work has sometimes been difficult to obtain because the value of doing basic science is often difficult for a non-scientist to grasp. Stratton was once asked by a Congressman, "What is a physicist, anyway?" Another Bureau director and a brilliant scientist, Dr. Edward Condon, was criticized by members of Congress for not being able to ". . . tell us so we understand."

Above. Antenna used in experimental time broadcasts. These broadcasts are part of a program begun at NBS over 50 years ago to broadcast standard frequencies. Such services have expanded so that they are currently making major contributions to the Nation's space and defense programs, to world-wide transportation and communications, and to a multitude of industrial operations, as well as providing convenient time services to thousands of listeners.

Below. Precision gage blocks produced at NBS during World War I. Before the war gage blocks, essential to the manufacture of interchangeable parts, had been imported from Europe. In providing these devices, NBS contributed to the war effort and freed American industry from one area of technical dependence.



When Condon assumed the directorship after World War II, he launched a campaign to revitalize basic research at the Bureau. A later investigation by a Congressional Committee confirmed the need for more emphasis on basic science, as did the Russian accomplishment in 1957—the launching of the first space satellite.

Industry

Just as much as a scientist in a university, Federal, or clinical laboratory, scientists and engineers in industrial laboratories need accurate measurement standards, precision measurement equipment, and ways of having such equipment calibrated. From the start NBS has worked to develop, expand, and refine such services. Now, rather than merely calibrating instruments, the Bureau is striving to check entire measurement systems: equipment, procedures, and people. This kind of check makes measurements very literally 'traceable to NBS.'

Another area of critical importance to industry is the work NBS has done and is doing in determining the composition and properties of materials. Knowing what a material contains and how it behaves under a variety of conditions is key to deciding what applications that material is suited for. The Bureau has tested materials ranging from cement, brick, steel,

paper and glass to new synthetic fuels and exotic polymers.

An important class of materials standards has been produced and sold by NBS since 1906. These standards samples, now called Standard Reference Materials, are well characterized materials of known composition. They are useful in such areas as quality control in industry and in the calibration of measurement equipment.

In some cases, industry cooperates directly with NBS to accomplish a research goal. Since the 1920's Research Associates—scientists and engineers working for various private organizations—have come to the Bureau to undertake projects of mutual interest. Some liaisons—as the NBS affiliation with the American Dental Association—have been so strong and productive that they have gone on for decades. This particular program has produced quality dental materials and procedures and the high-speed dental drill—the device that in the late 1950's replaced its slow and often torturous predecessor in dentists' offices across the country.

It would be misleading to depict the NBS-industry association as wholly harmonious. Product testing has been one area of occasional dispute. Since 1904, when the Bureau began testing products for other Federal agencies, industry has from time to time challenged the right of the Bureau to do such testing and to make public the results. But over the years, standards and specifications set for the products that government buys have helped bring quality merchandise to the market—from good ballpoint pens to sound nuclear power plant pressure vessels. Working with private standards-making groups, trade associations, and technical societies, Bureau staff have broadened the effort to help develop and promote the standards industry needs to produce better products more efficiently.

Many important American industries, not least the building industry, have been strengthened by Bureau

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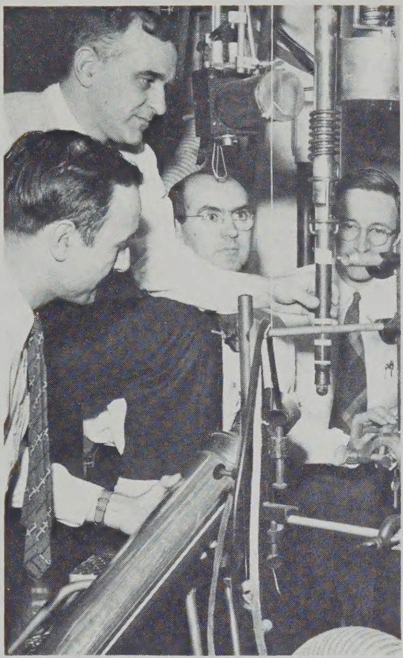
A Basic Quest



An experiment that shattered a fundamental concept of nuclear physics was conducted in 1956 by physicists Dr. Ralph Hudson, Dr. Ernest Ambler, Dr. Dale Hoppes, and Dr. Raymond Hayward (L-R) of NBS, and Dr. Chien-Shiung Wu of Columbia University (not shown here). The concept was that of parity conservation in quantum mechanics. Basically, parity conservation means that two atomic systems, one the mirror image of the other, will behave identically. Though accepted for many years, some laboratory work had brought this concept into question in connection with the "weak interactions." Physicists Dr. Tsung Dao Lee of Columbia and Chen Ning Yang of the Institute for Advanced Study in Princeton surveyed the experimental information on the parity concept and suggested a number of experiments that would settle the dispute. Because of its advanced capabilities in low-temperature alignment of atomic nuclei, NBS undertook a project involving cobalt-60.

The approach taken was to measure the amount of beta radiation emitted in a specific direction when cobalt 60 nuclei were aligned by an external magnetic field. In order to achieve such alignment, the cobalt was cooled to 0.01 K, a step that reduced thermal agitation to the point where alignment was possible.

Once aligned, the amount of beta radiation emitted in a selected direction was carefully measured. The applied magnetic field was then reversed, polarizing the cobalt nuclei in the opposite direction, and the beta emission was again measured from the same detector location. Rather than being equal, as the law of parity implies, the amount of radiation detected in these two measurements was different, proving that the cobalt-60 nucleus has a beta emission distribution that is not a mirror image, and thus that the law of parity does not hold true.

When Lee and Yang accepted the 1957 Nobel Prize in physics for their theoretical work, they cited the contribution made by Wu and the NBS team.

Raise A Standard

continued

contributions. From early tests on construction materials and insulation to studies of the performance of whole buildings and involvement with developers of building codes and standards, NBS has assisted builder and user alike in achieving quality and economy. Bureau efforts have helped at times—as in the 1920-1921 depression—to improve the prospects for a troubled building industry.

One NBS project during World War I proved to be a windfall to the war effort and to a number of U.S. industries. Gage blocks, necessary in the manufacture of interchangeable parts, had up to that point been imported, primarily from Sweden. Acting quickly and efficiently, NBS produced the gage blocks essential to mass production and freed American industries from this type of technical dependence.

Another Bureau practice, beginning before World War I, helped launch several industries. As an adjunct to its research, NBS began to manufacture a number of materials. At one time the Bureau had 9 small, experimental "factories" operating at once, producing optical glass, rubber, paper, cement, clay products, gages, alloy metals, cotton, and wool. Today these activities are conducted entirely by the private sector. At the time, however, many industries lacked the resources to conduct essential research, and NBS work met a crucial need. NBS production of optical glass was also crucial to the Nation in two world wars and did not stop entirely until the 1950's.

Consumers

Dr. Stratton, who sometimes bemoaned the reticence of industry to accept the aid of science, saw the public as a lever to aid this cause. In 1915, the Bureau published its first consumer pamphlet, "Measurements for the Household." One section of the pamphlet warned people against using carbon lamps and urged that they buy tungsten lamps that consumed ⅓ the electricity. The publication made a strong case by saying. "The tungsten lamp has been improved in quality and reduced in price to such an extent that no customer can afford to use carbon lamps, even if he were paid a bonus on each lamp. . . . "

NBS had tried to persuade manufacturers to abandon the carbon products, but to no avail. To make matters worse, utility companies often gave away the carbon lamps. The "false economy" of getting something for nothing was evidently more of an inducement than saving energy and money. The Bureau effort to reach the consumer and effect a change seemed to do little immediate good, but, eventually, quality won out and the carbon lamp disappeared.

A 1917 circular, "Materials for the Household," did more than prove successful in making Bureau research accessible and useful to the public. It also served as the forerunner in terms of style and content of such publications as Consumer Reports and Consumer Bulletin.

Though the aim of some of the consumer information produced by NBS has been to motivate industry, this aim is by no means the primary one. Publishing consumer information is the principal means the Bureau has to transfer the benefits of its research directly to the people. NBS continues today to make available information on home security, the metric system, use of color, energy conservation, and research results in other areas of general interest.

Government

At times in its history, NBS materials specifications have helped government at all levels to improve the quality of goods it purchases. Measurement science aids the regulatory agencies in overseeing the health and safety of the people and the quality of the environment. Many of the programs at the Bureau are funded by other agencies, especially in the area of applied technology. State and local government efforts in areas such as weights and measures and building codes and standards are supported by NBS technical programs.

NBS over the years has maintained the broad scope of activities charted by its first director. But Congress, which must determine the ultimate directions, has repeatedly given new mandates or revised old ones. A comprehensive amendment of the enabling act, clarifying Bureau functions and removing Stratton's catch-all clause, was passed in 1950. Recent legislation has broadened the NBS role in areas such as computer science, standard reference data, fire research, energy conservation, and radiation safety.

Today NBS carries on its research in modern laboratories in two locations, Gaithersburg, Md., and Boulder, Colo. Facilities include a research nuclear reactor, an environmental chamber where complete houses can be tested, an anechoic chamber where experiments in sound are conducted, and a mechanical testing machine for applying and measuring tension and compression loads—one of the world's largest.

The standards work of the Bureau continues to be a major responsibility, as it has been since 1901, both at home and abroad. The Bureau often represents the United States in developing world-wide standards and cooperating with international research organizations so that accurate and compatible measurements and fair standards can facilitate international science and trade.

Over 75 years, the Bureau has faced difficult challenges. It has proved its ability to adapt to changing times and changing priorities. One thing, though, has never changed and has never been questioned: the devotion of the Bureau to the pursuit of technical excellence.

The following articles discuss a few of the many ways this excellence has been achieved, maintained, and used. □

Meeting The Measurement Challenge

by Arthur Schach
technical information specialist

The Institute for Basic Standards is central to the NBS measurement responsibility. Its goal: excellence of measurements in the service of commerce, industry and in the advancement of knowledge and protection of the quality of life.

In retrospect, Congress's decision in 1901 to set up a National Bureau

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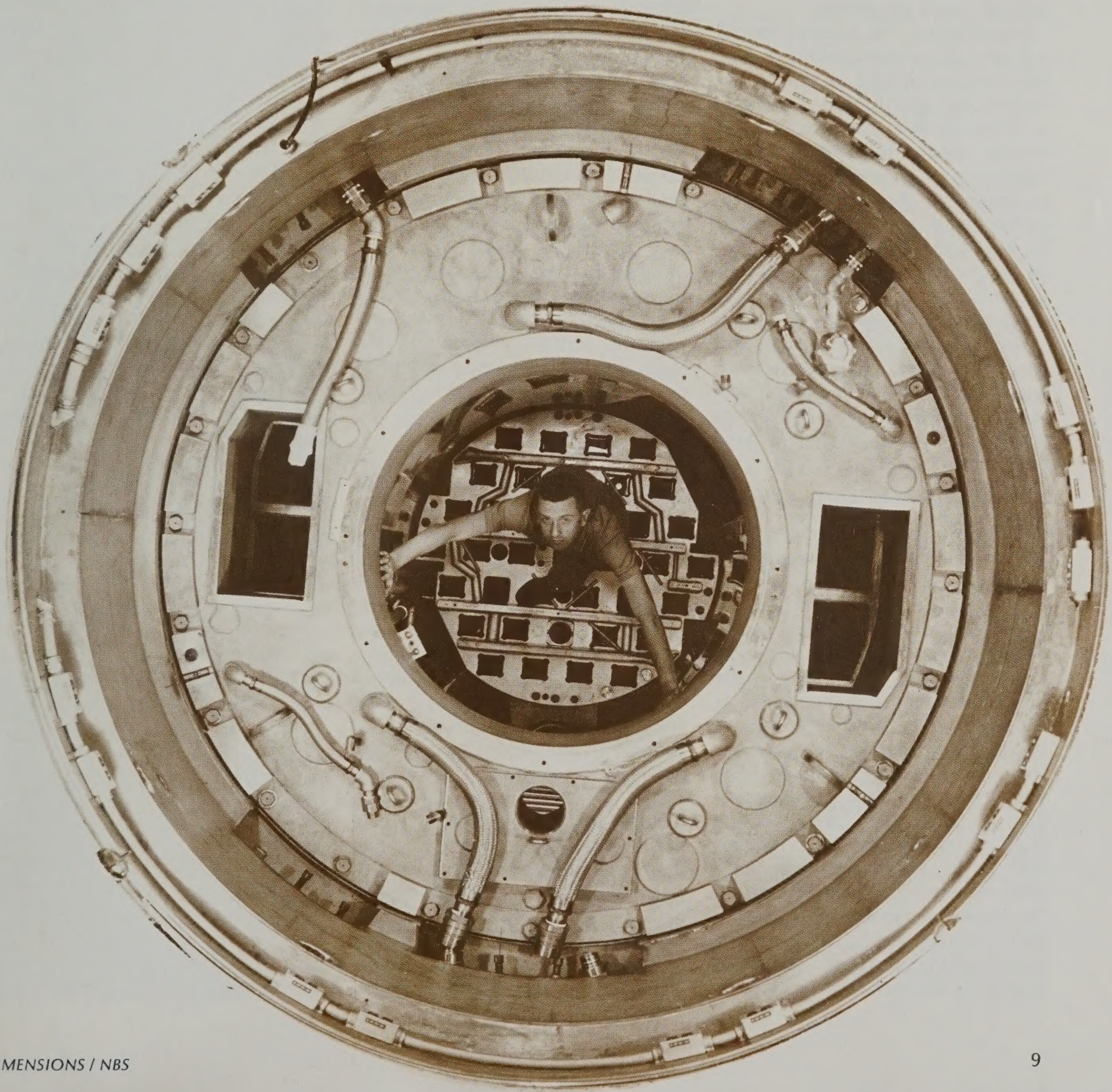
Looking into core of the NBS 10-million-watt nuclear reactor prior to its completion in 1966. A top plug completely seals the fuel transfer area, and the cavity around it is closed. Today, extensive research programs carried out at the reactor range from basic radiation studies to the development of solutions to some of today's urgent problems, in areas like energy, health and safety, medicine, crime, and the environment.



Meeting The Measurement Challenge

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of Standards came not a moment too soon for the new organization to begin contributing to the Nation's most vigorous, almost turbulent, period of growth, which even two world wars and a monumental Depression could not repress.

Measurement, the Bureau's special and most characteristic province, was fast being recognized as vital to the strength and growth of the economy, an indispensable resource of the coming age of industrial research. Shifting from a largely static to a predominantly dynamic mode, measurement science—metrology—would be constantly exploiting discoveries on the frontiers of science to provide scientists and engineers with measurement tools of ever greater power.

The following article suggests the challenging array of measurement needs that confronted metrologists at NBS and shows a few of the characteristic ways those challenges have been met.

The Need to Measure

THE idea that official, government-provided standards of weights and measures are necessary for fairness and mutual confidence in the exchange of goods goes back to the very beginnings of civilization.

Probably just as ancient is the idea of measurement that arises as people learn to match the sizes of things that fit together to make objects—legs of a table, door and doorway, wheel and axle. These operations, in the course of time, became more varied, precise, and complex. And the demand for them was multiplied many millions of times over by the coming of modern mass production methods which, without such measurement operations, would not have been economically feasible.

But only in the last century or so has there been widespread appreciation of measurement as a means of gathering precise and objective information about the physical world, an idea at the heart of the development of science as we know it today.

Those who started NBS on its way had all three of these functions of measurement clearly in mind, and all three of them have strongly influenced its programs down to the present. Nevertheless, the role of measurement in making things tended to predominate—especially considering that two centuries of industrial revolution had expanded the concept of "making" to include techniques for harnessing natural stores of energy for man's use.

Thus the newly established NBS gave special attention to the needs of the burgeoning electric power industry, providing measurement services that would contribute to its long-term growth and to the efficiency of its day-to-day operations and would assure equity to consumer and producer. Since then, metrologists have worked to keep pace with the continuing expansion and shifts of emphasis in industry and its kaleidoscopic changes and innovations.

No Lack of Problems

Electrical industries, to which NBS early turned its attention, were especially prone to rapid transformation. Not only did an electric power industry exist in 1901, but there were already a million and a half telephones in use. That same year Marconi sent the first wireless signal across the Atlantic. J. J. Thompson had discovered the electron in 1897 and in 1907 Lee DeForest would invent the triode vacuum tube, the key to high amplification of electric signals.

These and other advances paved the way for radio, television, radar, thousands of ingenious and sophisticated applications of electronics, and, perhaps most important, for the computer and automation. Solid state integrated circuits and microminiaturization, for example, should soon allow us to duplicate—more likely, surpass— the performance of today's giant computers by devices no larger than a breadbox.

For NBS, all this (plus much there is no room to mention) has meant a proliferation of measurement types and techniques. Each new system—telephone, radio, television, radar—used alternating currents of successively higher frequencies—audio, radiofrequency, ultrahigh frequency, microwaves—calling for distinctly different hardware and measuring procedures. (The term "plumbing," applied to microwave components, suggests the contrast between microwave circuitry (operating, say, at 5 gigahertz) and that of an FM radio, for example, which operates at frequencies roughly 100 times smaller.)

At each frequency level, measurements are required, among other things, of current, voltage, power, attenuation, and impedance. In addition, measurements are needed of frequency itself, vacuum tube and transistor characteristics, directional characteristics of antennas, microwave standing wave ratio, electrical noise, and ionospheric conditions that affect the propagation of radio waves.

In addition to all this, the measurement *ranges* of the electrical quantities have broadened tremendously. Voltages, for example, now range from less than a microvolt up to a megavolt, a million million times larger. This usually means that a whole series of different measuring techniques and apparatus must be available to deal with different portions of the full range.

Even the old-established areas of direct current and low frequencies are still producing striking changes

When Bureau scientists in 1972 achieved the highest frequency measurement ever made, they laid the groundwork for one day linking the international standards for length and time. This important breakthrough was made by measuring the frequency of an infrared helium-neon laser whose wavelength was already known. The accomplishment made possible a 100-fold improvement in the determination of the speed of light.

such as the new digital voltmeters, stable to one part in a million, and experiments with cryogenic (very low temperature) transmission lines that may eliminate most of the considerable energy losses in electric power lines.

Nor are the electrical industries the only ones that have kept NBS metrologists well supplied with challenges. Others include:

• Automotive and aviation industries: measurements of fuel energy content and efficiency of use, combustion characteristics, precision mechanical parts, air resistance and turbulence, fatigue of metals, navigation data.

• Industrial and medical use of new radiations: standards and procedures for measuring source and beam intensities of electrons, protons, and gamma rays from accelerators and radioactive materials; neutrons from nuclear reactors; infrared, ultraviolet and x-rays; and most recently, coherent light from lasers.

• Space exploration: measurement of thrust of rocket engines, flow rates of liquid oxygen, dimensions of high-precision guidance devices, solar energy collectors, telemetry equipment.

• Chemical industries: synthesis of plastics, nylon, and thousands of other man made substances with their new demands on spectroscopic and other methods of chemical analysis, measurement of temperature and high pressure, sizes of microscopic particles, flow rates of liquids, chemical reaction rates.

• Metallurgy: measurements of chemical composition, strength of materials, magnetic properties, high temperatures, and, more surprising, very low pressures in connection with vacuum techniques for producing special alloys.

In all these areas, and others besides, NBS has provided measurement services and helped develop and improve the needed standards, instrumentation and procedures.

A very special development has, in the last decade or so, added a new factor (new at least in its strength and general acceptance) to the measurement scene—an emphasis on safety and environmental protection in the public interest. While NBS shares no direct responsibility for making or enforcing any of the large number of regulatory laws adopted in recent years, it can and does provide technical information needed in formulating meaningful regulations, and standards and measurement methods needed to determine compliance with regulations based on technology.

This new humanizing emphasis on safety and environment is in effect a "fourth dimension" added to the three mentioned earlier. That is, not only are measurements needed to acquire basic knowledge of how things behave and why, for making other things out of the available raw materials and energy, and for measuring the quantities of what has been made so they can be fairly exchanged in the marketplace. Measurements can also help decide how well a process or product performs its intended function and to what extent it may have negative effects that nullify its positive advantages.

The Professionals

We now turn away briefly from the world that spawns the welter of measurement problems we have just been pointing to, to consider the kind of professional activity that goes on inside the NBS Institute for Basic Standards. For, though the measurement needs that NBS attempts to meet arise mainly in the daily round of living and working, its viewpoints and practices are closely tied to the disciplines of pure and applied science. These disciplines put a high premium on care and patience—which most people automatically associate with accurate work—and on a great deal more.

"Very carefully" is, in fact, only half the answer to the question: "How do you make an accurate measurement?" The other half is: "Very intelligently"—the best judgment and imagination one can muster.

This means, especially at the highest levels of accuracy:

• Understanding the relevant theory, experimental techniques, and instrumentation, particularly (today) the highly flexible and versatile resources of electronics.

• Appreciation of the possible sources of error as gained by exhaustive studies of how measurement re-

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Meeting The Measurement Challenge

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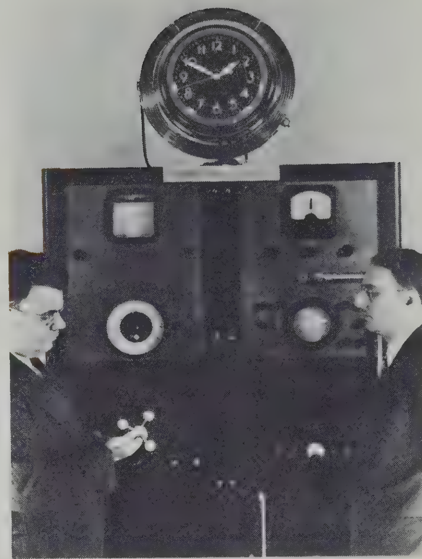


Same time, same place, same people—a difference of 25 years. Left, 1949. Dr. Edward Condon, then director of NBS, poses with Harold Lyons, who headed the NBS clock program. They are standing in front of the world's first atomic clock, and NBS development that measured time by the vibration of an ammonia molecule. At right they are pictured again on the 25th anniversary of atomic timekeeping. Today's atomic clock system is based on the frequency of a cesium atom and is accurate to about one part in 10^{13}. If it could run for a million years without any adjustments, it would still be correct to within 4 seconds.

sults are affected by different conditions and ways of using the apparatus.

- Ingenuity in designing the measurement so as to isolate the apparatus from sources of error, to "play one source of error against another" or otherwise keep the effects of disturbing factors at a minimum.
- Alertness to breakthroughs in science and engineering that can be applied to advance the art of measurement.
- Understanding of the physics needed to evaluate the feasibility of a proposed measurement and the statistical techniques for extracting the maximum information from measurement data and in estimating its quality.

One area where NBS must work at "the highest levels of accuracy" is in monitoring the stability of the national standards of measurement (such as the standards for the meter, kilogram, volt, ohm and second) by comparing them with those of other countries. Another is in the research to find better standards—standards of higher precision for advanced industrial research and science. Still another is in measuring certain constants of nature (the speed of light, Avogadro constant, gyromagnetic ratio of the proton, and others) that play a part in other measurements. (The speed of light is used, for example, in radar techniques for measuring distance.)

Thus, the national standard kilogram, a cylinder of platinum-iridium alloy, can today be compared (in less than 4 hours) with another such standard with an uncertainty of no more than 2 parts in a billion. In 1901 the uncertainty was only a few times larger but the operation required nearly a year to carry out.

In research on better sources of radiation to use as wavelength standards of length, NBS has developed stabilized lasers that could provide a length standard at least 100 times more precise than the present official standard which is based on a spectral line from krypton and has a precision of 4 parts per billion. The prototype meter bars of 1901 had a precision of about one part in a million.

The most recent measurement of the speed of light at NBS had an uncertainty smaller than 1 part in 100 million. In the early part of the century, the best determinations, including that in 1907 by Rosa and Dorsey at NBS, had uncertainties of around 1 part in 10 thousand.

Skills like those needed at this high level of metrology are indispensable for the high quality required in NBS services to industry and science. As far as industry is concerned, a survey of its needs was recently completed by the Institute for Basic Standards. This was part of an attempt to bring into focus major features of the National Measurement System—the aggregate of all measurements made in the U.S., plus the associated structures of technical personnel, industries, laboratories, instrumentation and measurement procedures. The number of measurements needed and the problems they raise will call for the best that NBS can do.

Fortunately NBS does not have to shoulder the responsibility alone. There are other standards and precision measurement laboratories in the United States—laboratories of the larger corporations, independent private laboratories, and those of government agencies like the Energy Research and Development Administration, the National Aeronautics and Space Administration, and the Department of Defense. And there are the weights and measures organizations of the individual states concerned with the use of measurements in local trade—the accuracy, for example, of grocery scales and gasoline pumps.

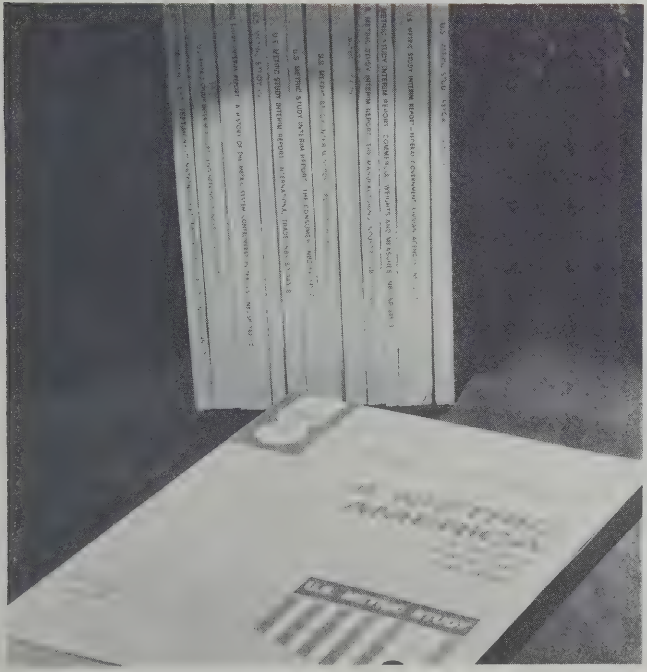
NBS, however, maintains the national standards of measurement that can verify the accuracy of the standards and reference instruments of other laboratories. Usually these laboratories send their standards or instruments to NBS to have them

"calibrated"—that is, to have their correct values or readings determined by comparing them with the national standards. (The current catalog of NBS measurement services lists about a hundred distinct types of calibrations.) Or NBS will at regular intervals send carefully measured objects to the laboratories which make their own measurements on the object and return it to NBS where checks are made to see that the value has not changed in transit. The advantage of such a Measurement Assurance Program, as this is called, is that it tests the laboratory's entire measurement process, not just its standards.

We have made the tour from the world to NBS and back. Considering again the motives that lead people to measure, we discern a common spirit in the respect for accuracy and the desire to describe things as they are, to make things fit together, and to design apparatus that functions as it should. In short, the world of measurement activity is a principal contemporary refuge of the ancient spirit of responsible craftsmanship and pride in work—what the American economist Thorstein Veblen called "the instinct of workmanship." □

Metric

The metric system developed in France in 1790, was legalized in the U.S. in 1866 and received international acceptance with the signing of the Treaty of the Meter by 17 Nations on May 20, 1875. As a result of the Treaty, the International Bureau of Weights and Measures was founded to maintain standards of the metric base units and coordinate measurement systems of member nations. The International Bureau's first job was to construct prototype standards with the U.S. receiving prototype meter and kilogram standards in 1890.



The National Bureau of Standards has been associated with the metric system since its founding. NBS has maintained the prototype standards that are the basis of our national measurement system. The Bureau has also represented the U.S. at the General Conference on Weights and Measures, held every six years to establish international measurement policy.

In 1968 the Congress asked the Department of Commerce to undertake a comprehensive study of the metric system and recommend a course of action for this country. NBS performed that study and, in a 1971 report, recommended a policy of voluntary conversion to the metric system. The fruits of that study were realized when President Ford signed the Metric Conversion Act of 1975 last December 23. It is now declared national policy that the United States government will encourage a voluntary changeover to the metric system, guided by a 17-member U.S. Metric Board.

NBS through The Years

The National Bureau of Standards provides the basis for all physical measurements in the United States and applies technology to help solve the Nation's problems. Staff and facilities have expanded over the years as NBS has worked to carry out its mission. In 1901, the staff numbered 12. Today there are 3,100 full time employees.

Above left. The smaller of the two major NBS sites located in Boulder, Colorado. The Boulder laboratory has 14 buildings on 83 hectares. Above right. The NBS site in Gaithersburg, Maryland has 27 buildings on 233 hectares. NBS has maintained field locations and institutes in various parts of the country—and other areas of the world. The Bureau disseminates time, frequency, and weather information from several radio stations.

HIGHLIGHTS FROM THE PAST

1904—Development of First Neon Tube—Commercialized and a new industry founded about 1930.

1908—First Postgraduate School in Government Established—Now conducted in cooperation with universities in the Washington area.

1914—Precise Determination of the Faraday—A classical determination of an important physical constant that stood until a recent redetermination at NBS.

1915—Development of Radio Direction Finder—Now in general use by all commercial airlines.

1922—First AC Radio Set—Development of the first alternating current radio set was perhaps the most revolutionary development in radio; it put radio in the home.

1930—Measurement of Constant of Gravitation—An historic redetermination of an important constant of nature.

1934—Preparation of Heavy Water —Provided the experimental basis for Urey's Nobel Prize-winning work.

1938—The Electric Hygrometer—Greatly increased the accuracy of measurement of humidity in radio meteorography; now standard for present-day radiosondes.

1941—Radio Proximity (VT) Fuze for Bombs—The proximity fuze was widely used during latter part of World War II and was considered second in importance only to the atomic bomb.

1944—First Successful Guided Missile: the Bat—The only automatic, homing guided missile carried into large-scale production and used in combat during World War II.

1946—Electrodeless Plating of Nickel—Now the basis of multimillion dollar industries.

1946—Printed Circuit Techniques—First used in production of radio proximity fuzes, these techniques are now widely used in the manufacture of electronic assemblies.

1949—The Atomic Clock—The initial NBS developments paved the way for later versions at NBS and elsewhere.

1949—Gyromagnetic Ratio of the Proton—The first direct measurement of an important physical constant, leading to the revision of accepted values for other significant quantities in physics.

1950—SEAC (Standards Eastern Automatic Computer) Dedicated—First automatically sequenced, high speed, electronic digital computer in the United States.

1956—A Bureau experiment first demonstrated that the quantum mechanical law of parity conservation does not hold in beta decay. This experiment disproved a widely accepted fundamental concept of nuclear physics, thus clearing the way for a reconsideration of existing theories.

1958—The gyromagnetic ratio of the proton was redetermined by measuring the precession rate of protons in a magnetic field. The new value made possible more accurate values of many fundamental constants such as electron charge-to-mass ratio, e/m, the magnetic moment of the proton, and Planck's constant, h.

1962—NBS published the first production line book in which the tables were composed by a photocomposition machine controlled by the output of a digital computer.

1963—The National Standard Reference Data System was established to disseminate critically evaluated data on the physical and chemical properties of materials authoritatively documented as to reliability, accuracy, and source.

1972—Bureau scientists achieved the highest frequency measurement ever made, raising the possibility of replacing the definitions of the units of length and time by a single definition of the speed of light.

1974 — Isotope Separation-Significant enrichment of isotopes of chloride in boron through selective laser excitation was demonstrated.

NBS DIRECTORS

*Dr. Samuel Stratton, 1901-1922

*Dr. George Burgess, 1922-1932

*Dr. Lyman Briggs, 1932-1946

*Dr. Edward Condon, 1946-1951

*Dr. Allen Astin, 1951-1969

*Dr. Lewis Branscomb, 1969-1973

*Dr. Richard Roberts, 1973-1975

Above.The main home of NBS from 1903 to 1966 was at the corner of Van Ness Street and Connecticut Avenue in Washington, D.C. Crowded conditions and the need for modernization of facilities led to the move to Gaithersburg. Below. Until this permanent site was ready, NBS staff occupied part of the Coast and Geodetic Building in the 200 block of New Jersey Avenue, S.E., Washington, D.C.

75 Years of Progress through Materials Research

by Madeleine Jacobs
public information specialist

TODAY, we take the performance of many materials for granted. But before a product appears in a store, or a building is erected, or an airplane is assembled, a tremendous amount of time, effort, and money is spent assuring that the materials used to make the objects will be reliable and durable.

Since 1901, one of the continuing responsibilities of the National Bureau of Standards has been to develop and maintain basic measurement capabilities for accurately determining properties of materials and relating these properties to the performance of materials in service. The overall responsibility for materials research is vested in the Institute for Materials Research.

In the NBS research programs today, materials are analyzed by both chemical and physical means. Scientists and engineers study the composition of the material. Additives and constituents present in trace quantities are examined to see if these trace amounts will affect the performance of the material. Complex characterization procedures provide information and data on the structure and morphology of the material. Finally, the properties of the material are determined, particularly those related to performance in service.

Early Materials Testing

This type of total approach to materials problems guarantees that today, for example, when you buy a light bulb intended to burn 200 hours, you feel confident that it will be reliable and durable. But materials have not always been so dependable—and materials research has not always been so sophisticated.

An early example of materials research at the Bureau began in 1904 when the government called on NBS to find out what was wrong with its incandescent light bulbs. The bulbs, purchased at the rate of one million a year by the government, regularly and rapidly burned out in Federal office buildings.

The Bureau learned that the bulbs were neither uniform in accordance with the manufacturer's own standards, nor did they come up to the simple specifications suggested by the government. The Bureau soon found needs for improvements in the clinical thermometers, electric meters, chemical glassware, inks, mucilages, and, indeed, the whole catalog of supplies purchased for government use.

Soon, manufacturers started coming to NBS to obtain assistance on methods of measurement and quality control. NBS began to determine the

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Shortly after World War I, NBS acquired a cotton mill. In all the Bureau ran 9 small experimental factories.

75 Years of Progress through Materials Research

continued

physical and chemical properties and composition of materials in order to provide specifications to the industries involved. It also issued standard samples (now known as Standard Reference Materials) to help industry in its quality control. A unique relationship emerged between NBS and industry—a relationship that continues today. Thus, from the beginning, materials research at the National Bureau of Standards was in response to the requirements of a growing nation.

Railway Investigations

Metallurgical materials problems formed a significant part of NBS activities virtually from the day it was founded. The need for better analytical measurements, particularly in the burgeoning iron and steel industries, led to the Bureau's first standard sample in 1906—a group of ores, irons, and steels certified by chemical composition which aided in the production of steel. NBS also provided assistance on metallurgical problems to other government agencies such as the Bureau of Engraving and Printing.

Meanwhile, the Nation had become aware that a large number of railroad accidents were occurring due to faulty material used in railroad rails and car wheels. With the cooperation of steel companies, NBS began to study constituents of railroad iron and steel, heat stress and heat treatment, and related problems in the manufacturing process. The information gained in these long-term studies led to improved steel technology and manufacturing. By 1930, the rate of accidents from materials failures had dropped by more than two thirds.

During the same period, a new form of power for the Nation, electricity, was causing other serious metallurgical problems, including corrosion. Electrical current, from trolley car rails, strayed into water pipes and gas mains, causing widespread corrosion damage. Similar damage was found in underground light and power cables, bridge footings, and building support structures.

NBS began to study the problem. Until 1922, these studies were confined to corrosion due to stray current electrolysis and its control. After it became apparent that serious corrosion also occurred in soils under conditions that precluded stray currents as an explanation, a field burial program was initiated in order to obtain information on the effect of soil properties on the corrosion of metals. More than 36,500 specimens, representing 333 varieties of ferrous, non-ferrous, and protective coating materials, were exposed in 128 test locations throughout the country. A large number of manufacturers and users of materials for underground construction cooperated by furnishing materials and labor.

After almost two decades of research, a new approach to cathodic protection was developed at NBS. This involved the use of replaceable zinc anodes attached to the underground structure to be protected, thus making the structure resistant almost indefinitely to the adjacent soil.

World War I

These and other areas of materials research became even more important when the country became involved in World War I. The Nation was faced with materials shortages of some important materials and durability and reliability problems with other critically needed materials.

The metallurgy group turned its interest from rails and wheels to studying the chemical, physical, and structural properties of various metals and alloys used for shells, guns, armor plate, high speed tools, and aircraft. Out of these efforts, a number of significant technical advances were made. Wartime shortages of tin led to the substitution of cadmium for tin in solders and bearing metals. The compositions of some bronzes were modified and methods were developed for the recovery of tin scrap. Manganese was conserved through revision of specifications following laboratory testing.

The shortage of wool led NBS into studies which showed that fabric structure was more important than fiber content in determining the thermal properties of fabrics. This discovery led to development of cotton blankets as substitutes. Similarly, NBS and industry developed a cotton substitute for scarce linen for the wing frames of observation airplanes.

Optical Glass

Early Bureau investigations on cement were applied during the war to other materials, such as ceramics. When the supply of imported optical glass was cut off because of the outbreak of World War I, NBS Director Samuel Stratton directed researchers to study the manufacture of optical glass. A year later, NBS began to supply data to experimental glass plants set up by various commercial firms that had been urged to take on this work.

In May 1918 the War Industries Board ordered an all out effort to achieve large scale production of optical glass. Late in 1918 the Bureau began production in a new Kiln Building in Washington, D.C. containing eight melting furnaces. To assure a supply of optical glass for the armed services, the glass plant continued in operation on a small scale supplying glass to the Naval Gun Factory in Washington during the 1920's and 1930's. During World War II, glass production was again speeded up with the glass plant operating around the clock. Nearly 1 million pounds of high quality optical glass for the military were produced. With the end of the war, the optical glass program returned to a pilot scale operation, which continued until 1957. By then, it was apparent that commercial production was adequate to meet military requirements for the standard types of glass.

Dental Program Begins

After World War I NBS returned to its studies of a host of materials, including paper, plastics, rubber, textiles, leather, and clays. At the same time, the dental materials program got underway. This was to become one of the most enduring materials research programs at NBS. In 1919 the U.S. Army Dental Corps came to the Bureau for help in establishing standards for dental amalgams (used for fillings) of improved durability and quality. The first standard for amalgam alloy, completed in 1926, was done with such thoroughness that in 50 years it has only been revised once.

Shortly after this standard was issued, NBS's long standing cooperation with the American Dental Association began in 1928. The 1930's witnessed a great expansion in the research program. Emphasis was placed on basic research of the physical and chemical reactions of many dental materials. The period was productive and resulted in an improved understanding of the materials used in restorative dentistry. Over the years, the program has grown into a broad based effort directed toward development of measurements methods and data. Outputs of the materials program have been standards and test methods, new and improved dental materials, techniques, and instrumentation, such as the high-speed drill and panoramic X-ray machine.

World War II

The knowledge gained in all areas of basic materials research at NBS during the 1930's found extensive application in World War II. The story of the NBS response to the country's needs in World War II began in 1938 when NBS Director Lyman Briggs was appointed chairman of a committee to investigate the possibility of using atomic fission of uranium in warfare.

Early research at NBS was directed toward the production, purification, chemical analysis, isotopic separation, and physical properties and metallurgy of uranium and related materials. Samples of uranium and its compounds were collected and analyzed at NBS by chemical and spectrographic analysis. Experiments at NBS in 1941 on the purification of uranium showed that all critical impurities in uranium could be removed by a single ether extraction of a solution of uranyl nitrate. This method became the basis for the industrial production of uranium oxide. Studies of the conversion of uranium oxide to the metal resulted in procedures that were adopted in producing the metal, thus solving a serious problem in the production of high purity graphite for use as a moderator in the first atomic pile.

NBS methods for analyzing impurities in uranium became standard methods in the Manhattan Project. By 1943, NBS had been designated as the central control laboratory for uranium materials. In all, NBS made 30,000 analyses on 9,000 uranium samples. NBS also carried out pioneering work in the separation of uranium isotopes and developed standard reference materials of

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NBS and the American Dental Association have conducted a joint research program for nearly 50 years. Besides a series of filling materials used almost universally today, two major pieces of dental equipment have been developed in this program. The panoramic X-ray machine takes a picture of the entire dental arch, permitting rapid screening of large numbers of patients. Today's high speed air-turbine drill, that reduces cutting time and patient discomfort, evolved from a prototype developed at NBS in the 1950's.

75 Years of Progress through Materials Research

continued

isotopes both for uranium and plutonium. These materials continue to serve the country today for the accurate assay of enriched and depleted reactor fuel elements.

In the meantime, a young chemist named Harold C. Urey had become convinced that an isotope of hydrogen of mass 2, though unknown, could be found. In conversation with a friend from NBS, Urey mentioned that in his studies of the hydrogen spectrum he had found a satellite line next to the hydrogen alpha line that he thought might be heavy hydrogen. His friend suggested that he seek the help of the Bureau's cryogenics laboratory, where F. G. Brickwedde was doing low temperature research on liquid hydrogen.

By repeated low temperature distillations of liquid hydrogen, Brickwedde was able to achieve sufficient concentrations of the heavy hydrogen to unquestionably confirm its existence by spectroscopic measurement. Following this work, another NBS scientist, E. W. Washburn, produced heavy water by electrolysis. This procedure had been tried earlier by others and given up as unpromising.

Urey's discovery of the isotope of hydrogen and Washburn's separation were considered to be two of the major technological achievements of the 1930's. Discovery of the new isotope, which was named deuterium and won Urey the 1934 Nobel Prize in chemistry, set the stage for the preparation of essentially pure deuterium oxide, or heavy water. This provided the basis for the large scale production of heavy water for both scientific and technological purposes in the next decade.

Fundamental Properties of Materials

After the war, the new age of electronics, nuclear physics, and polymer research challenged the Bureau to provide new fundamental physical standards, physical constants, and standard samples. The decades of the 50's and 60's saw rapid growth in research on fundamental properties of materials. Underlying this research was the development of new and more accurate analytical techniques and instrumentation by NBS scientists and others. The same period also witnessed an expansion in the Standard Reference Materials program, which, by then, had become an integral part of NBS programs aimed at sharing measurement expertise with the scientific and engineering community, industry, and the public. Today, nearly 1000 SRM's on a host of materials are offered for sale. SRM's related to energy production, clinical analyses, and air and water pollution monitoring are the most rapidly growing areas.

During the past 25 years, materials research has shifted somewhat from studies of specific materials—such as metals, glass, and plastics—to studies of materials properties and performance in broad areas of national concern. These areas include materials problems in energy generating systems, materials conservation and utilization, health care, fire safety, and the environment.

Until World War I, all of the optical quality glass used in precision instruments came from abroad. Spurred by wartime shortages, NBS developed much of the technology needed to establish a domestic manufacturing capability. A key Bureau contribution was the development of a pot material that would not contaminate the molten glass. During the war years NBS developed a variety of special glasses, and later produced this 176 cm diameter mirror for the observatory at Ohio Wesleyan University.

The materials needs of innovative energy generation systems, such as magnetohydrodynamics (MHD) and coal gasification, are being studied at NBS. Magnetohydrodynamics, a

way of generating electricity from nuclear and fossil fuels, especially coal, has serious materials problems blocking the way to practical application. Bureau scientists are gathering information on MHD components under operating conditions in a cooperative effort with others in the U.S. and in the U.S.S.R. NBS scientists are also developing methods for measuring corrosion and erosion of materials being tested for use in coal gasification plants.

Materials Conservation

In the field of materials conservation and utilization, NBS is playing a significant role in encouraging the development of materials with better performance through its materials measurements, standards, and data activities. The Bureau's Nondestructive Evaluation (NDE) Program, for example, is aimed at developing NDE methods as well as standardizing new and existing NDE methods in an effort to detect flaws in materials and products, and develop tests that can predict performance over the lifetime of a material in service. Ultrasonic techniques, acoustic emission, and neutron radiography are some of the methods under study which appear to be especially promising. By the year 2000 tests of this kind will probably be used to insure durability and reliability of most materials—not only those used in high technology applications, such as nuclear reactors and supersonic aircraft, but in many consumer products as well.

Metallurgical research—always a major activity at NBS—today is also aimed at improving materials conservation and utilization. NBS scientists are studying the fundamental processes of corrosion and other events that cause materials failure. Through the development of measurement methods, data, and consulting services, the Bureau's metallurgical research program helps insure proper design, specification, and control of metallurgical processes so that the full range of properties of metals can be used effectively.

Another of the Bureau's significant materials programs, which has been a continuing effort since World War II, is the development of techniques to separate isotopes of elements, since some properties of materials depend directly on their isotopic composition. The recent advent of laser technology and the availability of lasers of relatively high power output has provided a new tool to attack this problem. Last year, a team of NBS scientists achieved the separation of isotopes of the light elements, chlorine and boron, using laser-stimulated chemical reactions. The resulting reactions yielded milligram quantities of enriched isotopic materials —amounts at least 10 times greater than previously reported. These isotopes of chlorine and boron, now expensive to produce, are important in medical, agricultural, and environmental research. For instance, compounds containing one of the boron isotopes are being studied for use in treating inoperable brain tumors. Isotopically enriched chlorine-containing pesticides could be traced through their environmental cycle.

In another important materials program, Bureau scientists are trying to learn the mechanisms of surgical implant failure and to define important properties of implant materials to help make them more durable. Working with an orthopedic surgeon, NBS scientists recently defined the properties and performance characteristics of a bone cement used in the many thousands of hip joint replacement operations performed each year by orthopedic surgeons. Their characterization of the cement will assure long lasting replacement of bones and joints that have failed. Research on metallic implants focuses on surface reactions, crevice corrosion, microstructures, and fatigue and wear, with special attention on titanium alloys. In a program partially sponsored by the National Heart and Lung Institute, the adsorption of important blood proteins on surfaces is being investigated to establish physical science criteria that can be applied in the evaluation of currently used or potential cardiovascular implant materials.

These and many other areas of materials research are contributing to the needs of the nation today. As these needs change, and the demands for data on the properties and performance of materials become greater, NBS will continue to meet the challenge. □

Science and Technology for People:

ONE of the reasons for establishing the Constitution, said the Founding Fathers, was to provide for the general welfare. Today when you turn on a water tap, watch the children board a school bus, or drive down a highway, you are probably taking advantage of some of the essential services provided by government.

These services are now so numerous and commonplace they are often taken for granted. This was not always the case. Until well into the 19th century, promoting the general welfare consisted largely of enforcing the law, educating the children, and, when necessary, burying the dead. In the time of Wyatt Earp, Dodge City, Kansas had a marshall, a school, and Boot Hill, but it had no sanitation services or building codes.

Following the advent of an industrial society came increasing government responsibility in the area of public welfare. As people migrated to the city they lost the self-sufficiency possible on the farm. The need for municipal services grew. Increasing industrialization required both uniform standards of production and restraint in the conduct of free enterprise which, if unchecked, could operate to the detriment of the public good. By establishing and maintaining unified, legal weights and measurements, by conducting research in areas such as the performance of materials and by setting standards to improve certain products, such as those set for the efficiency of gas appliances early in the century, the National Bureau of Standards has for 75 years worked to benefit the public.

More specifically, the Bureau has served the public in the past and continues to do so today in such areas as building science and technology, energy conservation, fire safety, consumer product technology, radiation research and, in recent years, environmental quality. It is important to remember that NBS is a research organization, not a regulatory agency. It provides technical expertise to industry and other government agencies, private standards-making organizations, trade organizations, technical societies, and State and local officials. By publishing information useful to the general public, the Bureau communicates research directly to the consumer, especially in areas related to the home.

In the 1920's NBS fire researchers conducted a number of experiments by burning abandoned buildings in downtown Washington. Data on rate of fire spread and structural damage led to development of new regulations for fire-resistant buildings. Fifty years later NBS conducted smoke and fire studies on seat cover and padding materials used in local buses.

Building Research

For 75 years, NBS has contributed to safety, durability, economy, and innovation in building construction. Building research has produced data on structural strength, fire resistance, acoustics and sound insulation, heating, ventilation, air conditioning, plumbing, and building material and electrical equipment. These test data have provided the technical bases for upgrading building codes and standards.

NBS' relationship and contributions to the building community can be traced in part through its publications, leading up to today's extensive building science series. The publication of technical primers and consumer handbooks began in 1922 when "Recommended Minimum Requirements for Small Dwelling Construction," appeared. This was followed by primers on plumbing, zoning, building codes and city planning. "How to Own Your Home," an NBS handbook for prospective home buyers was published in the fall of 1923 and sold 100,000 copies in the first week. This was followed in 1931 by "Care and Repair of the House," a 20-cent publication that sold more than 500,000 copies between 1931 and 1940. It remained available until the early 1950's.

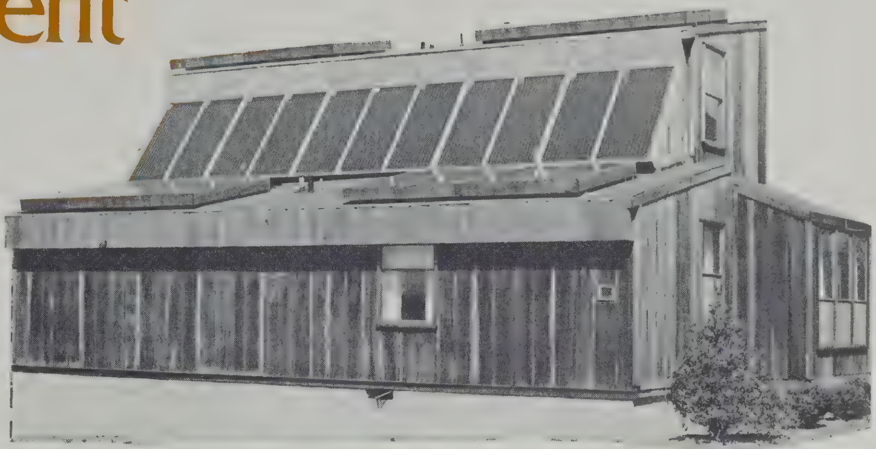
NBS prides itself on the ability to take a base of technical competence developed over the years and, through far-sighted leadership, to shape its current programs to meet the needs of the times. Today NBS building research activities provide technical and scientific bases for criteria and standards for both the materials and com-

Safety, Health, Public Benefit

ponents and the whole building systems and sites. The emphasis is not on materials specifications and design but instead on performance of components, structures, and systems.

The performance approach is impartial. It asks, for instance, that a wall perform certain structural and thermal effects regardless of what materials are used or how the wall is designed. With the emphasis on performance comes the opportunity for innovation, progress and economy not always possible under rigid, static rules.

Equally important, NBS considers the relationship between builder and user. The way a building is used and operated, after all, influences the performance of that building. And the components and design of a building can affect the well-being and performance of the occupants. One current study, for instance, is providing insight into the psychological effect of windows on people. While an office building with few or no windows might be highly energy efficient, will it also be conducive to the well being and efficiency of the occupants? NBS is seeking to answer such questions in conjunction with its energy conservation studies.



Solar collectors have been installed on the NBS townhouse where a number of energy conservation studies have been conducted.

Energy Conservation

Although energy conservation has only recently become a household word, the Bureau's work in this area goes back to 1910 when the American Society of Refrigerating Engineers asked NBS to provide usable data on heat transmission in insulation for design purposes. A precise method for measuring heat transmission was not available, and the first apparatus for this purpose, the guarded hot plate, was conceived and built at the Bureau in 1912. This apparatus, with modifications, is used to the present day.

A main focus since 1940 has been the investigation of the performance of whole buildings and their heating systems. In that year, the first NBS environmental chamber was completed—a rudimental predecessor of today's 2,000-cubic-meter chamber where outdoor temperature patterns can be rapidly simulated and controlled, from -45 to 65 °C (-50 to 150 °F). Since 1940 NBS has learned that improved methods of building construction, design, and insulation can cut energy use by up to 50 percent.

Following the practice of making Bureau research useful to the public, NBS has published several booklets on how to save energy, including the latest consumer report, "Making the Most of Your Energy Dollars in Home Heating and Cooling." Use this booklet, homeowners can calculate their best combination of energy improvements, based on their climate, energy prices, and investment costs. A guidebook for industry, "Energy Conservation Program for Industry and Commerce" (EPIC) and its supplement gives practical guidelines on energy saving for small and medium-sized companies and for corporate giants.

Fire Research

Another national priority—fire safety—has also been a concern at NBS since 1910. In that year, NBS joined with two private associations to undertake a joint study of the performance of building columns when exposed to fire. Fire research grew to involve tests on brick walls, gypsum partitions, treated and untreated wood partitions, and other building materials. Whole buildings have been studied for the spread of fire and smoke, and today, a new NBS fire research laboratory makes possible both small-scale and large-scale fire tests of building materials and constructions to help make the American home more fire safe.

Fire research has, especially in the last 2 decades, been recognized to require more than the study of buildings and building materials. A large fraction of fire deaths are attributable to the burning of the building contents and furnishings instead of the building itself. In a national effort to decrease loss and injury from fire, NBS is studying the flammability of many materials and products. For example, the current mandatory standards for carpeting, mattresses, and children's sleepwear are based on

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Science and Technology for People:

continued

NBS recommendations. A proposed flammability standard developed at NBS for upholstered furnishings is now under consideration by the Consumer Product Safety Commission. NBS is also working in other areas, such as smoke and fire detection, mass transit vehicles, and combustion product toxicity.

Consumer Product Technology

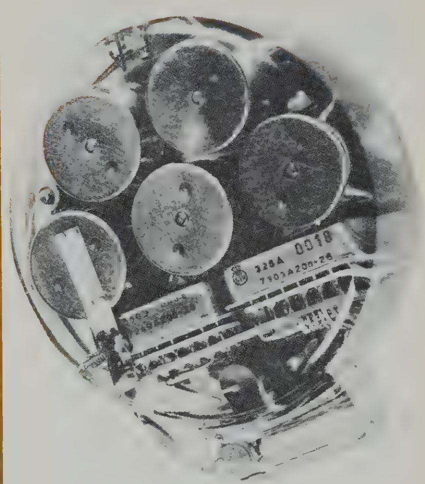
The government, as a consumer, has called upon the Bureau since 1904 to test a number of the products it has intended to buy—and sometimes to set specifications for those products. NBS has, in turn, made the results of such tests known without stating brand names. From time to time, this product testing has stirred discontent on the part of consumers, who want more, and on the part of industry, who wants no government "interference." During the 1950's the testing of a battery additive aroused such industry protest that the Secretary of Commerce forced a Bureau director to resign. The director, Dr. Allen Astin, was reinstated when the clamor on the consumer side and the integrity of the NBS work proved strong enough to counter industry ire.

Today, with growing Federal interest in consumer rights and protection, a number of technically oriented consumer programs are underway at NBS to evaluate the safety, energy efficiency, and other performance characteristics of consumer products and equipment for the law enforcement community. Recently, a voluntary Department of Commerce energy labeling program for household appliances, developed by NBS, has been made mandatory. Although the program is now under FEA, NBS continues to develop methods for determining the energy efficiency of these appliances, including televisions, water heaters, and refrigerators.

Radiation Research

Although the NBS Institute for Applied Technology has responsibility for carrying out the programs just discussed, work in other parts of NBS is as directly related to 'the general welfare.' Singling out a few programs in safety and health reveals only a small part of the total effort.

One such program, radiation safety, began in 1913 when NBS received a phial containing 20.28 milligrams of pure radium. The Bureau did not start developing X-ray and radium protection standards until 1920. But hospitals and doctors began sending their radium salts to NBS for analysis as soon as they discovered the Bureau had acquired the international standard of radium.



Technology can literally be life-saving, as in the case of this cardiac pacemaker. Part of electronic technology work at NBS concerns pacemaker technology—semiconductor device measurement, hermeticity testing, metallurgy, standards making, and technology transfer.

Today NBS is providing much of the technical basis for the work of the Bureau of Radiological Health, the agency responsible for setting mandatory standards for electronic product radiation. Within the last few years, NBS has developed measurement methods and instruments for BRH to use in assuring the safety of such products as microwave ovens and in establishing safe practices in radiation treatment.

Obviously, many regulatory agencies find NBS an important technical resource when it comes to protecting the public. NBS assistance ranges from cooperation with the Energy Research and Development Administration in developing standards for nuclear power plants to research for the Consumer Product Safety Commission on toy safety.

Environmental Quality

Within the last decade, a new area of national concern, the quality of our environment, led Congress to create the Environmental Protection Agency. NBS over the years has developed basic measurement competence in measuring trace amounts—sometimes as low as a few parts-per-billion. Since 1970, this measurement competence has been applied to the area of environmental measurement to assist EPA, industry, and other government agencies in pollution abatement.

EPA, for instance, must have accurate and generally accepted methods of measurement and reference standards in order to make regulations and administer its programs. Industry needs a firm base of measurement in order to comply economically with these regulations. NBS, working impartially to develop measurement methods and standards, aims to make it possible to protect the public health at minimum economic expense. Toward those ends, NBS provides: standards for measurement, improved measurement techniques and instruments, calibration of measurement systems, and scientific information and data.

Although much work in environmental quality is done for the Environmental Protection Agency, other areas of government, including the Navy, seek NBS measurement expertise.

It is especially in the applied areas, such as those just discussed, that the link between Bureau research and public benefit is most apparent. But a main goal of NBS, in all areas of research, is the task of "making science useful and technology humane."

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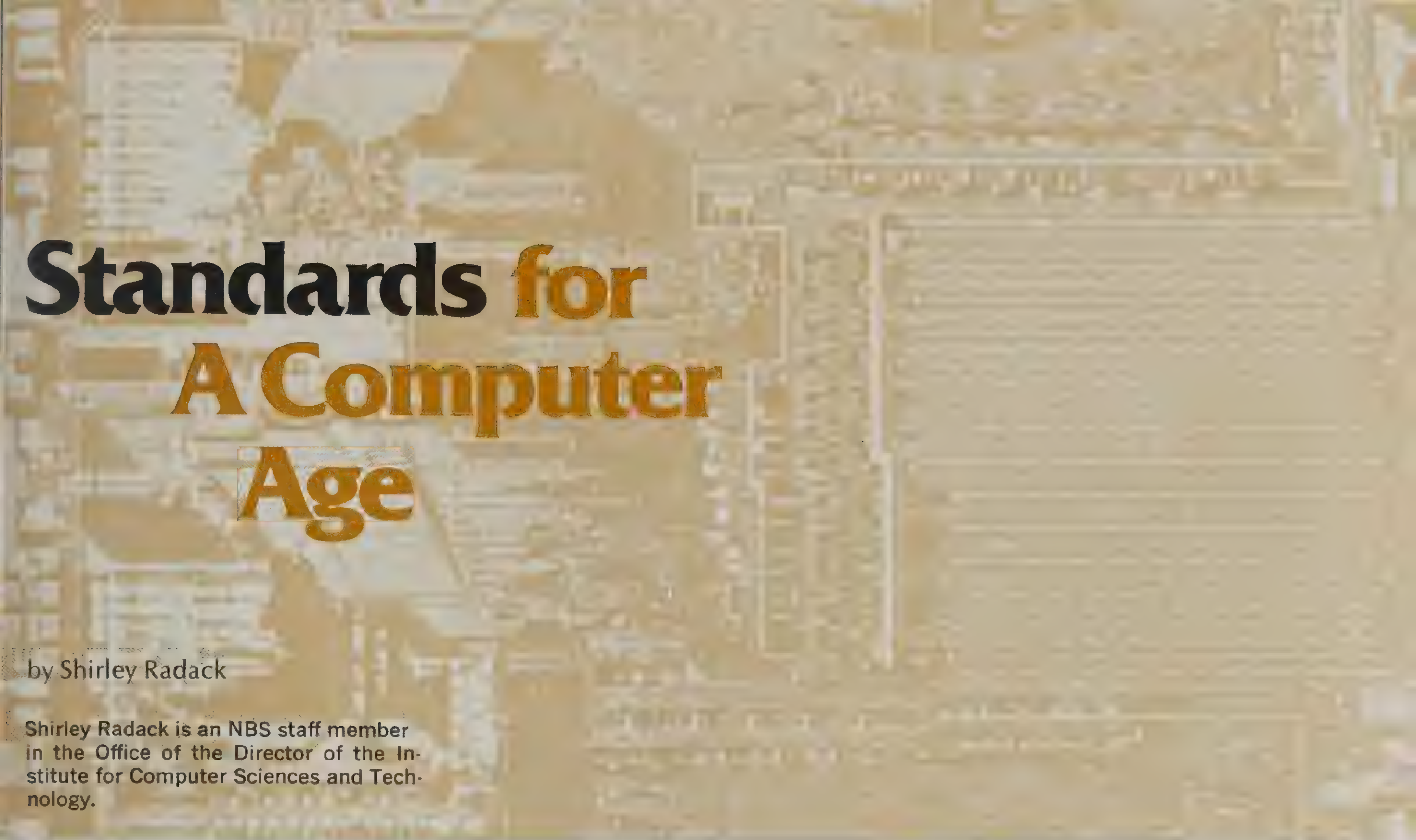

Standards for A Computer Age

by Shirley Radack

Shirley Radack is an NBS staff member in the Office of the Director of the Institute for Computer Sciences and Technology.

"TWENTY computers—that number will handle computing requirements in the United States for 20 years." This estimate came from a group of scientists 30 years ago when the electronic computer was a gleaming new question mark in the future of science and industry.

Were the experts right? At the end of 20 years, not 20 but 60,000 computers were humming away coast to coast, some of them at speeds thousands of times faster than their early predecessors.

The forecasters used a sound method and good data to make these predictions, but obviously they underestimated on a grand scale. Why? No one could know that the computer would give rise to whole industries; that new methods and types of computation would develop; that the computer, as a true extension of man's mind, would become much more than a calculating machine. A glimpse at the future of computers would have astounded the scientists on two accounts: the quantum changes themselves and the brief time frame in which these changes have occurred.

Changes

Today there are more than 200,000 general purpose and minicomputers in the United States. Spectacular technological achievements have reduced the cost and size of computers and increased their speed of operation dramatically. Computers are now about 1/100 of the cost, occupy 1/800 of the space, and perform 10,000 times faster than those of 20 years ago.

Accompanying these changes in technology have been equally dramatic changes in the character of American society. No longer are we a society primarily engaged in manufacturing goods. We have become a service society, with three-quarters of us earning our livings by performing services such as health care, education, transportation, communications, utilities, retail trade, banking, and insurance.

The management of information is crucial to the service society, and computers are essential to the efficient management of information. In education, computer-aided instruction systems are utilized; grades and student records are computerized. Airline, hotel, concert, and theater reservations are handled by computer systems. The voluminous health care records in many hospitals are now automated. The retail trade is heavily using information processing for its operations, as is the banking community. The Federal Government is dependent upon computers for many activities such as air traffic control, Social Security, and many areas of national defense.

In the past, the main thrust of computer technology was to improve equipment reliability, to increase the speed of operation, and to miniaturize components and reduce the cost and space requirements. Today, problems reflecting the rights and interests of the individual, the organization, and society clamor for attention. Automated information handling increases the opportunities for misusing data either accidentally or intentionally. Advances in technology such as remote terminals and computer networks make information in computer systems easily accessible. As a result, public apprehension about computer systems has been aroused.

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Standards for A Computer Age

continued

History

NBS involvement with computers dates back to the early days of computer technology. In the 1940's and 1950's, when Federal agencies began investing in electronic computers to process an increasing volume of data and perform complicated calculations, Bureau experts designed one of the first computers, SEAC, and played a lead role in developing computer applications.

The intensive technological developments of the 1950's were followed by the growing concerns in the 1960's about the escalation of Federal Government computer expenditures. A comprehensive review of government policies on the acquisition and use of automatic data processing equipment was ordered by the late President John F. Kennedy. Arising from this study was the recommendation for the establishment of a "centralized research center on computer sciences and technology."

Legislation enacted by Congress in 1965 established Department of Commerce responsibilities for improving the use of computers by Federal agencies. The NBS Center for Computer Sciences and Technology which was set up to carry out these responsibilities was elevated organizationally to an Institute in 1972.

Today the Institute for Computer Sciences and Technology (ICST) carries on a multi-faceted program to improve the efficient utilization of computers by the Federal Government while reflecting current concerns about computers, information processing, and automated systems. Highlights include:

- Software, Data, and Equipment Standards
- Privacy and Security
- Networking
- Software Management
- Automation in Manufacturing and Services

The Federal Government is the largest computer user in the world, with an inventory of more than 8,600 computers. With computer systems, the Federal Government can cope with its massive record-keeping. However, incompatibilities between computer systems and computer produced information are costly. ICST attacks this problem through a very important program of computer standards. These standards provide the basis for more effective use of data, software, and equipment by Federal users and for improvement in the quality of computer products and services.

Standards

ICST, through its standards program, has managed the development of 44 standards and guidelines as Federal Information Processing Standards. These standards deal with programming languages, hardware calibration testing services, software testing, codes, data, transmission, documentation, optical character recognition, and computer security.

NBS has participated in the voluntary industry standards development of 79 national and 86 international standards. The latter are key to assuring that our Nation's computer products are afforded equal treatment in world markets.

New needs for standards are continually being identified. ICST is currently working with GSA to develop interface standards for components such as input and output devices to make it easier to link them to computer systems. By providing for greater flexibility and interchangeability of equipment, these standards can potentially make computer use by the Federal Government more effective and less costly.

Another high priority need in standards development is that for data element directories. These directories are important for the efficient identification, definition, and location of data in both manual and automated data systems, and will contribute to the effective use of data resources and data security measures.

Privacy and Computer Security

Concerns about individual privacy have intensified with the increasing use of automated information systems. Enormous amounts of personal data are stored in tens of thousands of computers operated by government and the private sector. Improper use or unauthorized disclosure of personal information can intrude upon an individual's privacy, leading to a denial of his rights and privileges, damaging his reputation, or causing embarrassment or inconvenience. Reacting to these concerns, Congress passed the Privacy Act of 1974, requiring Federal agencies to establish information management controls and procedures for the collection, maintenance, and disclosure of information about individuals.

ICST is playing a key role in the development of standards and guidelines needed by Federal agencies to put the Privacy Act into effect. Since computer management in the past has centered on efficient and economical operation, there is a need for properly designed information handling practices and technology for computer security. Work aimed at overcoming both of these deficiencies is being pursued.

An Encryption Standard. ICST has initiated the development of a standard encryption algorithm. An encryption algorithm is a set of mathematical steps for scrambling data so that it is intelligible only to authorized users. The publication of the encryption algorithm as a Federal Information Processing Standard is scheduled for 1976. Encryption can also be implemented in hardware using a single electronic chip (less than .635 centimeters on each side) which incorporates all the logic elements of the algorithm.

Access Control. The recent proliferation of computer terminals brings many people in contact with computer systems and makes the protection of personal information more

difficult. New technology is needed to control access to computer systems by effecting positive identification of users. Finding an inexpensive, but effective means for verifying personal identity, which can be used with or built into computer terminals, is of high priority. Methods using personal characteristics such as handwriting, hand geometry, speech, and fingerprints are being examined.

Physical Security. Damage to computer systems and their information by natural disasters or by persons with malicious or fraudulent motives can be costly. Guidelines have been issued to assist Federal agencies in security planning, controlling physical access to confidential data, and protecting valuable computer facilities and data from hostile activity or environmental hazards.

Networking

Computer networks with their flexibility and convenience for users are extensively utilized by government, education, transportation, banking, and retail trade organizations. Computer networks are the interconnection of computer systems and terminals through communications facilities. The simplest network is a single computer made accessible to a number of remote terminals through the dial telephone systems. A more complex form is a series of individual computers interconnected through dedicated, high-speed communications lines. Federal agencies have invested heavily in computer networks to reduce the cost of computer usage by enabling the sharing of hardware, programs, and data.

ICST programs help to match Federal users with computer networks which meet their needs. ICST has developed two tools to improve network utilization. One, a network measurement machine, collects data on the responsiveness of a network to individual user requests for service. This data is then analyzed to assess the network's ability to provide such service. The other, a network access machine, executes complex network procedures and protocols in response to simple user commands and makes networks more easily accessible.

Continuing efforts to improve the efficient use of networks will focus on:

- Developing methods for comparing the performance of networks and network services during Federal procurement.
- Improving performance of existing Federal computer networks.
- Devising standards for interconnecting computer networks.

Computers in Government The NBS Role

Public Law 89-306 (Brooks Act) provides the basic framework for the Bureau's role in improving the management of Federal Government computers in conjunction with the Office of Management and Budget and the General Services Administration.

The scientific and technical responsibilities assigned to the Bureau are:

1. to provide agencies, and the Administrator of General Services . . . with scientific and technical advisory services relating to automatic data processing and related systems, and
2. to make appropriate recommendations to the President relating to the establishment of uniform standards.
3. to undertake the necessary research in the sciences and technologies of automatic data processing, computer, and related systems, as may be required . . .

Software Management and Performance Measurement

Computer programs (software) have always been the most costly and unreliable aspect of data processing. The Federal Government spends at least $1 billion annually for software development and maintenance. ICST programs attack the problems of improving the quality of software and of evaluating the performance of computer systems. Work is being done on developing tools and methodologies to measure computer system performance, such as "benchmark" programs which can be used to compare the performance of computers.

Errors in computer programs can disrupt government activities. ICST emphasis on quality controls, testing standards, and improvement of programmer productivity is directed toward eliminating the costly errors and restoring public confidence in computer services. As an example, a service has been instituted to test the quality of COBOL compilers acquired by the government to assure that they conform to Federal standards.

An important area for future ICST action is that of functional fidelity of computer systems. Very simply, functional fidelity is the accuracy with which computer systems perform their required functions and the certainty that they are not performing any non-intended function. Computers are commonly used as the primary control element of systems that initiate actions with little or no human intervention. Failures of such real-time control systems for air traffic, mass transit, or nuclear power plants could cause catastrophic loss of life and property. Failures of information systems such as criminal justice, credit reporting, or voting could deprive an individual of his rights. Failures in payroll and banking systems could result in waste of public funds and loss of confidence in public institutions. Assuring functional fidelity requires both better management practice and new technology.

Automation

A major national concern has been the slowing down of our rate of productivity growth since World War II. Automation, the use of machines and devices to assist as well as replace human control functions, offers the potential of increasing productivity and of substituting for workers in dangerous jobs.

The ICST automation technology program has focused on the application of computers in the automatic

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SEAC, one of the first computers, was designed and developed at the National Bureau of Standards in the late 1940's. It was placed in operational use in 1950. SEAC had more than 100,000 connections and components and was the first general purpose, stored program computer running in the U.S. It performed for 4,000 hours without a malfunction during its first 9 months of operation and was used for 14 years. Applications included computations on electronic circuit design, optical lens calculations, statistical sorting and tabulating studies for the Social Security Administration and the Bureau of the Census, design of supersonic nozzles, and computing data on the crystallography of cement compounds and the penetration of X-rays. Portions have been preserved in the Smithsonian Institution.

control of machines in both manufacturing and service tasks. For example, computer programs can be used to direct machine tools and dramatically cut costs of manufacturing and at the same time increase output and protect workers from hazardous situations. In the service sector, improved productivity is expected to result from work on standards for the automation of pattern recognition applications such as examination of X-rays and blood cells, fingerprints, and earth satellite photographs.

Cooperation with Government and Private Sector

ICST actively cooperates with government agencies and with private organizations and applies its special competencies in computer technology to many unusual problems. A few highlights of recent cooperative activities include:

- Development of a computer-based system for the automated processing and matching of fingerprints.
- Assistance to the Department of Commerce in setting criteria for controlling the export of computer technology to Communist-bloc countries.
- Development of a remittance-processing machine for the Internal Revenue Service to speed up the handling of taxpayer payments with resulting savings for the government.
- Provision of design and performance specifications to the Navy Department for a low-cost robot manipulator system for ordnance handling and disposal.
- Development of guidelines for the use of computers in vote tallying for the Clearinghouse on Federal Elections.
- Cooperation with the National Retail Merchants Association in the formulation of a voluntary standard code for identifying and marking retail merchandise which can be read automatically at point-of-sale terminals in stores.

Future

Making predictions about the future of computers is as risky today as it was 30 years ago, for many of the same reasons. Considering all that the experts know about computer science and technology, they are still dealing with a question mark. There is more ahead than behind in terms of change in the equipment and software of the computer systems; computer capability will expand and new applications arise; some changes seem "predictable," some not; and as the computer changes it will in turn act as a powerful instrument of change in science, industry, government, and society.

Dr. Ruth M. Davis, head of the NBS Institute for Computer Sciences and Technology, stresses the importance of a strong foundation to support the coming changes. She says "ICST provides a technical basis for policy, legislation, and regulations." And, according to Davis, the Institute acts as spokesman for the application of computer science and technology ". . . in the best interests of concerned industries, concerned users, and concerned Federal, State, and local governments." □

Staying Afloat in a Sea of Data

National Standard Reference Data System

by Michael Baum
staff writer

"IF I have seen further, it is by standing upon the shoulders of Giants," Sir Isaac Newton wrote 300 years ago. Any scientist or engineer would understand—you build upon the work of those who went before.

Working scientists and engineers constantly use the experimental results of others in their own research. These data—values such as energy levels or rates of reaction—represent years of experimental work that has already been done, work that the scientist does not have to repeat before going on to something new. There is a problem however, in locating data buried in the archives of the scientific literature and making sure that it can be trusted.

What is needed is a source of data that is accurate, reliable, and accessible. Since 1964, one group in particular has been working to meet that need, the Office of Standard Reference Data (OSRD) of the National Bureau of Standards. This office, headed by Dr. David R. Lide, Jr., coordinates the National Standard Reference Data System, a group of Government and private data centers that collect, evaluate, and store experimental results from a wide variety of fields.

Scientists have worked at the systematic compilation of data reported by many different laboratories since the 19th century. John Dalton, while working on his own chemical atomic theory, compiled a table of relative weights for several elements and compounds based on the work of other scientists in 1803. Mendeleeff's periodic table of the elements, first assembled in 1869, is a classic work of data compilation.

Later years brought the idea of a continuing data collection effort, where the original work would be constantly updated and revised. The Landolt-Bornstein *Tabellen*, which first appeared in 1883, was one of these. The Landolt-Bornstein tables began their sixth edition in 1950, the last edition to attempt a comprehensive listing of physical and chemical data.

A similar project, the *International Critical Tables of Numerical Data, Physics, Chemistry and Technology*, which was completed in 1933, was the first data project to stress a critical evaluation and selection of experimental values.

Data collection projects at the National Bureau of Standards date back more than 50 years. A comprehensive table of thermodynamic properties was published in 1952 as NBS Circular 500. Another important project of this type produced three volumes of data on atomic energy levels between 1949 and 1958 as NBS Circular 467.

All such efforts tended to be random individual projects until 1963 when the National Standard Reference Data System (NSRDS) was established. The idea of the NSRDS was to provide a central organization that could coordinate the activities of the many government and private data projects and give overall direction to their work.

An important function of the NSRDS is the critical evaluation of data. The data centers do no original measurement, but they are essentially embedded in the research programs within the laboratories where they are located. They try to determine the accuracy of values reported in the scientific literature. There are several ways of going about this.

In some areas, thermodynamics is a good example, there is a detailed and well-developed theory to refer to. Data are cross-checked with values predicted by theory for consistency, something that the individual researcher does not always do.

The details of the experiment that produced the data are also checked for hidden sources of error. Since the researchers manning the data centers are themselves scientists intimately familiar with the techniques and problems of that particular field, they usually know from personal experience which experimental methods are reliable and which are not.

Another important function of the NSRDS is to report to scientific laboratories on what measurements are needed, or what measurement techniques have been found to be unreliable.

One data center, for example, found that a new technique for meas-

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Staying Afloat in a Sea of Data

continued

uring the viscosity of molten salts, although popular and in extensive use, had never been calibrated against figures obtained by the older measuring procedure. The center found that the values determined by the two different techniques were consistently different.

The Thermophysical Properties Research Center of Purdue University, as a result of a critical survey of thermal conductivities of elements, published a long article in *Science* magazine listing hundreds of measurements of thermal conductivities that were suspect and where new experiments were needed. The researchers were surprised to discover, among other things, that they could find no reported experiments at all on the thermal conductivity of calcium, one of the most common elements.

Within the OSRD, data evaluation projects are grouped into four categories according to the major applications of the data. The Energy and Environmental Program includes projects dealing with data that have an important application in some aspect of energy research and development or environmental research. Examples include chemical kinetic and spectroscopic data.

Data, especially thermodynamic data, that apply to the design and operation of processes in the chemical and metallurgical industries are grouped under Industrial Process Data.

The Materials Utilization Data Program covers properties required for materials selection and research and development of new materials. This category includes the structural, optical, electric, magnetic, and mechanical properties of solid materials.

Finally, the Physical Science Data category includes projects which involve basic data of very broad application, or which are associated with an important frontier field of science. Examples are fundamental physical constants, data on fundamental particles, and data particularly relevant to astronomy, biology, or other disciplines.

Today the NSRDS, managed by the Office of Standard Reference Data, numbers some 43 individual data centers and other projects across the country. Over half are located at NBS itself, either in Gaithersburg, Md. or Boulder, Colo. Some, like the Radiation Chemistry Data Center at Notre Dame, are located at universities. Others are located in private laboratories, such as the Superconductive Materials Data Center run by the General Electric Company in Schenectady, N.Y.

In addition, there are some separate centers, like the JANAF (Joint Army, Navy, Air Force) Thermochemical Data Project in Midland, Mich., that cooperate with the system without being under NSRDS management.

The "components" of NSRDS are as varied as their locations. On the one hand, there are small data projects, usually made up of one scientist or a small group, working on a strictly one-time project to compile a set of data, generally as part of their normal scientific work. At the other extreme are the large, continuing data centers. These centers constantly monitor published scientific literature in their individual fields, indexing reports and papers of interest, gathering all the numerical data and maintaining the whole in permanent data banks where the information can be retrieved.

The number and types of projects funded under the NSRDS change periodically with the completion of one project and the starting of another. Generally there are between 40 and 50 projects, including the continuing data centers, going on at any one time.

Data projects seeking NSRDS support must meet certain criteria. In particular, the data to be collected and analyzed must be useful to large segments of the technical community or applicable to a variety of different research areas, and there must be a sufficiently large amount of data to make the collection and evaluation worthwhile.

In addition, the area of application should be one where accurate, reliable figures are needed, and where the figures can be adequately evaluated and checked against clearly defined standards.

Compiling and evaluating data within the NSRDS program are not sufficient in themselves however. Equally important is the task of disseminating the information, making the data available to the scientific community. In addition to the formal publications of the program, the NSRDS data centers distribute their wares in a variety of ways. On the most direct person-to-person level, a phone call to the relevant center will often produce the needed figure immediately.

Occasionally, projects arise which call for close cooperation of one or more data centers with other government agencies. In 1971 the controversy over the use of the supersonic transport, or SST, raised questions about how the exhaust gases of the high altitude plane would affect the ozone layer of the earth's atmosphere.

When the Department of Transportation's Climatic Impact Assessment Program began a massive effort to study the chemical reactions involved, they found some of the needed data on reaction rates already compiled by the NSRDS Chemical Kinetic Information Center (CKIC) at NBS. Working with the Department of Transportation, the NSRDS Center issued a series of kinetic rate constant tables that are now used by every group modelling stratospheric chemistry, ensuring that the results from the different research groups are comparable and uniform.

With the recent discussion on the use of chlorofluorocarbons and their effect on the ozone layer, the data banks of CKIC have again become a focus of need.

In 1974 the American Society of Mechanical Engineers published *Combustion Fundamentals for Waste Incineration*. Although burning waste products to dispose of them may seem a fairly simple process, in reality the vast variety of materials burned in public and industrial incinerators gives rise to several problems, including how to dispose of possible noxious gases, at what temperature the mixture should burn, and how to best design an incinerator for the minimum amount of pollution. The ASME handbook provided thermodynamic data to make the necessary calculations for over 1,300 different substances that might conceivably find their way into a public or industrial incinerator.

The tables of data were supplied by the NSRDS Chemical Thermodynamic Data Center at NBS from their files. The CTD center assembled the tables in 6 months. Without the center the job would have taken much longer and cost several times as much.

In 1968, the Congress passed the Standard Reference Data Act (PL 90—396) which gave Congressional backing to the program, and, in addition, gave the NSRDS an authority that is very unusual in the Federal government. Unlike most Federal programs, the NSRDS has the authority, delegated by the Secretary of Commerce, to apply for and hold a copyright on its publications.

This makes it easier for the NSRDS to deal with private publishers of books and journals. In 1972, in cooperation with the American Chemical Society and the American Institute of Physics, the NSRDS began publication of a quarterly *Journal of Physical and Chemical Reference Data*. In the four full volumes of the *Journal* to date, the NSRDS has made 71 separate data compilations available to researchers.

Over 1,200 universities, industrial laboratories and individuals in this country and abroad regularly subscribe to the *Journal*. Thousands of others buy individual reprints.

Some NSRDS tables are published in cooperation with private organizations in book form. The ASME waste incineration handbook was such a case. On a more ambitious scale, the Joint Committee on Powder Diffraction Standards, in cooperation with NSRDS, published *Crystal Data Determinative Tables* in 1973. A mammoth work, the tables list 24,000 different crystalline materials. A computer typeset the tables, and over 1,700 copies have been sold since publication.

Some large collections of particular importance are stored on magnetic tape to be read by computers, and are available to users in that form. Recently, for example, over 11,000 mass spectra compiled by the Environmental Protection Agency and the National Institutes for Health were made available on magnetic tape to users, who have a choice of buying access to the computer on which the data are stored or buying a copy of the tape itself.

Another service still in the development stage at the OSRD is the use of TODARS (Terminal Oriented Data Analysis and Retrieval System), a self-contained computer program package that will take a wide variety of data files in many different forms and automatically search the files for needed information and perform a variety of elaborate correlations and analyses.

Further information may be obtained from Dr. David R. Lide, Jr., Office of Standard Reference Data, National Bureau of Standards, Washington, D.C. 20234. □

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... was established in 1901 ... Nation's science and technology and to promote their effective application for public benefit. The Bureau has organizationally divided its functions into four major institutes:

- The Institute for Basic Standards provides the central base within the United States for a complete and consistent system of physical measurements and coordinates that system with measurement systems of other countries.
- The Institute for Materials Research conducts research to provide a better understanding of the basic properties of materials and develops methods and standards for measuring their properties to help the Nation's scientific, commercial, and industrial communities put materials to the best use.
- The Institute for Applied Technology conducts and applies research and puts into practice, in a form that can be used by government, industry, and the general public, the technology developed in such areas as building, fire, domestic standards, electronics, and consumer product performance and safety.
- The Institute for Computer Sciences and Technology develops standards and provides scientific and technical guidance for the effective use of computer and automation technology in the Federal government.

The institutes are supported by the Office of the Associate Director for Administration; the Office of the Associate Director for Programs, which performs policy development and program analysis and planning; and the Office of the Associate Director for Information Programs, which promotes the optimum dissemination of information into and out of NBS and which manages the National Standard Reference Data System and international programs.

A five-member Visiting Committee of leading scientists and industrialists advises the Secretary of Commerce yearly on the scientific well-being of NBS programs and on the condition of facilities and equipment. Approximately 240 individuals from outside the Bureau serve on the Evaluation Panels that closely scrutinize Bureau projects. Members of the panels are appointed by the National Academy of Sciences—National Research Council. Findings are reported to the NBS director and the Visiting Committee.